Space Technology Research Grants

Design and Optimization of Space System Architectures: Applying and Extracting Lessons Learned

Completed Technology Project (2016 - 2020)

Project Introduction

TABS 11.2.6, TABS 11.3.3, and TABS 11.4.2 call for improvements in tradespace exploration and analysis technology that takes advantage of model based system engineering approaches. These technologies would support mission design and other decision-making by 1) searching the space of decision variables and identifying Pareto optimal solutions and 2) identifying the key tradeoffs in the objectives and the driving decisions. Maturing these technologies is critical for system architecture design because the architecture has the largest impact on downstream decisions and on the system's performance, cost, risk flexibility, and other figures of merit. Specifically, NASA is interested in applying tradespace exploration and analysis technologies to distributed spacecraft missions (DSM). Designing DSMs are a challenge because of the large number of design variables and their complex interactions, many nonlinear constraints including power requirements and link budgets, multiple conflicting objectives of maximizing performance while minimizing cost and risk, and local optima present in the tradespace. System models are being developed to evaluate a system, but optimizing the architecture and understanding the tradespace remains difficult. Multi-objective evolutionary algorithms (MOEA) show promise as a decision-support tool, because they can solve problems that are non-linear, non-convex, and continuous or discrete. MOEAs have been used in tradeoff and sensitivity analyses by NASA, the Aerospace Corporation, and JAXA. MOEAs, however, are computationally inefficient because they rely on stochastic sampling of the decision space and do not leverage the knowledge of the problem structure or the domain. A more efficient optimization method is needed to handle the challenges associated with designing DSMs. The proposed research will develop a knowledge-intensive optimization method that exploits expert-knowledge to explore the tradespace, much like how concurrent engineering design teams rely on expert experience. The knowledge-intensive optimization implements a multi-objective hyper-heuristic that adapts its search strategy to use an effective mix of codified expert knowledge and stochastic sampling. To make sense of the possibly millions of solutions returned by the optimization, researchers are just beginning to develop tradespace analysis technologies that visualize the relationship between design variables and objectives. The proposed research will develop a knowledge-extraction module to produce a more compact summary of the driving decisions that lead to optimal solutions using association rule mining and classification trees. Association rule mining will identify the design decisions that have large impact, and the classification trees will use these design decisions and create a partially ordered list indicating their relative importance. The proposed technologies will be demonstrated on DSM design case-studies to validate their efficacy.

Anticipated Benefits

These technologies would support mission design and other decision-making by 1) searching the space of decision variables and identifying Pareto optimal

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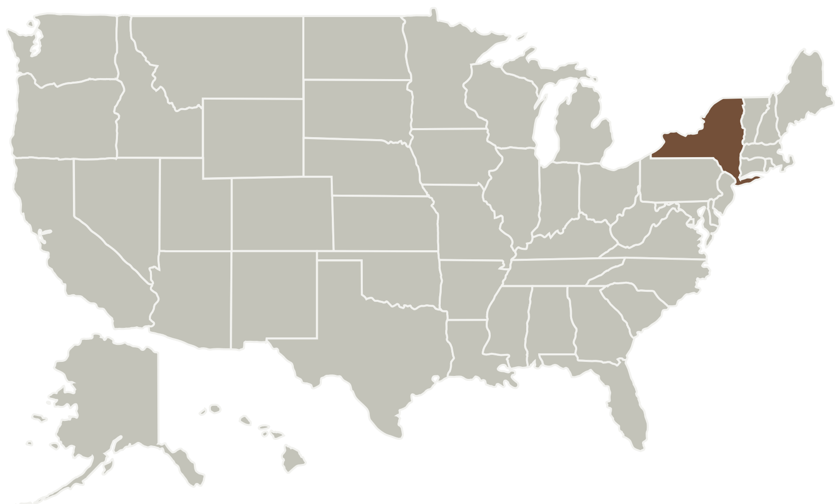
solutions and 2) identifying the key tradeoffs in the objectives and the driving decisions.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Cornell University	Lead Organization	Academia	Ithaca, New York

Primary U.S. Work Locations
New York

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Cornell University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Daniel Selva

Co-Investigator:

Nozomi Hitomi

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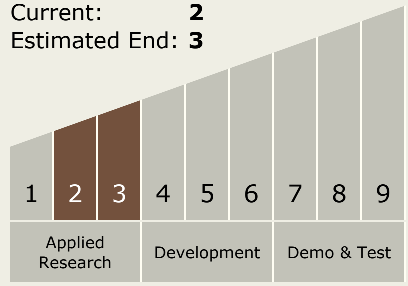
Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
  - └─ TX11.5 Mission Architecture, Systems Analysis and Concept Development
    - └─ TX11.5.2 Tools and Methodologies for Performing Systems Analysis

Target Destination

Foundational Knowledge